TECHNICAL REPORT 4669

STUDY OF LEVELS OF PACKAGING/PACKING OF CONTAINERIZED AMMUNITION

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JUNE 1974

PICATINNY ARSENAL
DOVER, NEW JERSEY

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report 4669	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Study of Levels of Packaging/Packing of Containerized Ammunition		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) CPT Richard V. McGaughy		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Picatinny Arsenal Ammunition Development & Engineering Directorate Dover, New Jersey 07801		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS Code 4932.05.4265.1
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE June 1974 13. NUMBER OF PAGES 57
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Containerization
Containerized ammunition
Packaging
Temperature
Humidity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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ABSTRACT

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CONCLUSIONS

1. During the period ammunition is in the container, the present package provides over-protection against induced environments such as rough handling. Reductions in this area may accomplish significant savings by reducing the amount of materials and tare weight (Table 1).

2. Little or no packaging changes can be made for high density items such as separate loading projectiles, which are almost self-protecting. However, single plant loading of projectile and propellant would facilitate containerization by effective utilization of weight and volume capacities.

3. Due to moisture buildup in containers in long term (over 6 months) storage, additional protection from natural environments may be required. These effects may be offset by a ventilation system.

4. Unitized loads will still be required prior to delivery to forward firing sites.

5. Containerization is most effective for direct shipments which cannot be preplanned during peacetime such as those from the plant to the theater of operations.

6. Due to facilities, storage requirements, and load restraint, shipments to CONUS Depots are slightly more costly then conventional methods.

7. Use of containers forward of the Forward Ammunition Supply Point (FASP), feasible with Heavy Lift Helicopter (HLH) and container transporter development, can be allowed by the user for certain situations resulting in possible unitizing reductions.

RECOMMENDATION

Proceed with Phase II design efforts to realize the savings indicated in Table 1. Savings on other items may be realized by the continuation of efforts beyond Phase II on an incremental basis.

INTRODUCTION

In recent years commercial industry has found the use of large freight containers to be economical in the handling and shipping of materials and products. In addition to cost savings realized by more efficient handling methods, there is less damage to the cargo because of rough handling at dockside. These shipping methods have proved so effective that merchant shipping is rapidly converting to container vessels and most new ships being built are designed for some type of containerized shipping.

With the trend of merchant shipping toward containerization, it is doubtful that available break-bulk vessels will be sufficient to adequately handle ammunition shipments during mobilization. Under those conditions many future shipments may necessarily be containerized for port handling and shipment.

About one-third of the total ammunition handling between manufacturer and user is at port facilities. The container affords increased protection against rough handling and weather.

For this study, it is assumed that: (1) all ammunition is to be shipped in ANSI/ISO 8' X 8' X 20' shipping containers from a CONUS point of origin to an overseas forward ammunition supply point (ASP). (2) Containers may be used for temporary storage at the forward ASP until ammunition is issued to the user. (3) Commercially owned containers, modified to restrain cargo, will be used.

Phase I is survey of Army logistics and user segments to determine the effect of 100% containerization of ammunition on organizations and mission operations, and to determine the impact of reduced levels of packaging and packing on their operations.

Phase II is a detailed analysis to determine the degree of packaging and packing reduction or reconfiguration that can be achieved, while retaining item protection during its life cycle. This phase would include review, redesign, and test of packaging for several typical items, such as mortar, fixed artillery, and semi-fixed artillery ammunition. Tests will be conducted for evaluation of the effects of temporary storage on Quantity-Distance and Storage Compatibility grouping. This phase will also include reevaluation of testing criteria for the reduced level of packaging/packing by TECOM.

SUMMARY

This study required a detailed review of the present ammunition logistics system and a visualization of the system as it would be with maximum use of containers. Natural and induced environments throughout the system were evaluated. Previous studies were reviewed and available data evaluated, including results of studies and tests of other type containers, shelters, and vehicles. User representatives of combat, combat support and combat service support organizations provided information used to assess the impact on missions at organizational, direct support and general support levels, including supply, maintenance, surveillance, equipment changes, and safety.

Interface of Containerization with Ammunition Logistics

Under the present system of break-bulk (unitized load) handling (Fig 1) ammunition is shipped by truck or rail from the load plant to the CONUS depot for long term storage. As required ammunition is removed from storage and shipped by truck or rail to a CONUS user or to a port facility for ocean shipment. In some cases shipments are made direct, bypassing the depot. At the port facility ammunition is handled by a combination of forklift trucks and slings or nets to lift it into the ships hold for stowage. The load is rigidly blocked in place on each mode of transportation.

Overseas (Fig 2) ammunition is removed from the holds using slings or nets; and, because most overseas port facilities for ammunition are limited, especially in a combat theater, it is often moved to shore by lighterage. Cargo is then loaded on truck or rail for movement to a rear depot and from there to an ASP and forward ASP (Fig 3). At each stop palletized ammunition must usually be handled two or more times.

Policy is for ASP's in the rear part of the combat zone and forward part of the COMMZ to be used for stockage of theater reserves with operating supplies to be shipped direct to the forward ASP or using unit from depots in the rear area of the COMMZ. Due to rapid changes in the combat situation and time-distance factors, resources are seldom available to effectively and efficiently plan throughput resupply.

For most items the unitized load (pallet) is not usually broken until the using organization (battalion or battery) begins to unload it, and then mainly because of the lack of handling equipment. When the ammunition

reaches the user it is often removed from the outer box and handled in the inner container only to reduce the excess tare weight. Subsequent moves require repackaging.

Containerization reduces handling at various transfer points and eliminates the effort involved with blocking at those points. Due to the configuration of present depot facilities and explosive storage requirements, there are no container storage areas. Ammunition must be removed and placed inside igloo magazines to maintain quantity-distance requirements. The situation at overseas storage bases is similar to that of CONUS depots; however, during support of an active theater, waiver of explosive storage requirements would allow some temporary storage in containers (Fig 4).

Containerized ammunition in the theater of operations would be beneficial in reducing logistics manpower requirements by use of heavy equipment. Since containers would remain loaded and the load restrained, this method would provide faster response to shipping requirements. Terminal points in the combat zone (Fig 5) for containerized shipments will be dependent on user requirements for each type of ammunition. In the case of some high usage systems, such as artillery, large containers may be delivered forward to the organization gun sites.

Comparison of Environments

Throughout its life cycle, ammunition is subjected to a variety of induced (handling and transportation) and natural (temperature and humidity) environments. Packaging is designed to protect the end item from damage and/or deterioration brought on by those environmental conditions. The effects of the environments on types of packages in and out of the outer pack were analyzed.

The basic ammunition packaging unit is the individual container, which is designed to protect against natural environments and normally provides only minimal protection against rough handling. To assist manual handling and provide adequate protection against rough handling, individual containers are consolidated into a packing box, normally made of wood. For handling, package sizes were usually limited to 50 pounds for a one-man carry or 120 pounds for a two-man carry. Personnel moving ammunition packed in this configuration learned to use pendulum action and momentum to assist in lifting the heavy boxes. It was also found easier to drop a box from the truck and then lift it to normal carrying position. The extra stresses applied to handles and cleats reduced the life of those parts

resulting in failures, thus accidental drops, during handling; and these box-to-box and box-to-ground shocks require a stronger package.

During the recent "Vietnam Era" of combat operations, great use was made of helicopters for combat and logistics. Because of aircraft weight limitations and packaging disposal problems in the combat forward areas, it became common practice to strip off the outer box, representing a 20% weight saving, and transport the inner containers in cargo nets to the gun site.

The impacts during manhandling frequently produce loading of over 100 g-units for a relatively slow pulse, thus inducing high stresses in the packaging material.

As new handling equipment was developed several boxes were unitized on a pallet base with the complete unit weighing about 2000 pounds. The unit allows each box to share the load and handling damage is reduced. Because of the weight of the unit and the necessity for using materials handling equipment which can move the units more slowly, pallet loads are not subjected to impacts as great as for manual handling. There are far fewer cases of dropping a pallet load than of dropping boxes from a truck bed. Due to variation in operator skill and judgement, there are cases of forks being jammed into a pallet or box, one load being rammed against another, pendulum impacts using slings, etc. During the time that packages are unitized, the impacts are about one-tenth as severe as those incurred during manual handling.

Handling equipment is limited to logistics and rear support areas; therefore, at some point mechanical handling must cease and manual handling take over. Man-portable packages must be designed to protect the ammunition from the rough handling to which they are subjected.

Moving ammunition or other cargo by an intermodal system such as RO-RO or large shipping containers further reduces the shocks against the packaging. A RO-RO system generally subjects the cargo only to transportation environments, including TOFC, and handling is minimal. Large freight containers must be handled mechanically at ocean ports and sometimes at other transfer points. Because of the large size and weight of these containers, handling is done more slowly and carefully then it is with pallet loads, and handling shocks are less. During normal port or transfer handling MILVAN type containers are subjected to shocks in the range of 1 to 2 g-units and usually less than one g.

Like handling, transportation produces a special environment. There are the shocks induced by impact of the transport vehicle with some object in the route, and there are vibrations or cyclic shocks induced by the vehicle or the route surface. The key difference is repetition.

Each mode of transportation has its own unique vibrations (Fig 6). In ocean ships there are the constant vibrations from the engines and other mechanical equipment and the lower frequency movements due to the movement of the ocean. Railroads have the vibrations induced by rail joints and by flexing of car couplings which vary more with speed. Trucks are subjected to the mechanical vibrations of the vehicle and those due to uneven road surfaces. Aircraft are subjected to the high-frequency vibrations of the engines and to occasional vibrations induced by air currents.

These differences impose a variety of requirements on the amount and nature of packaging materials to be used. Low frequency vibrations and shocks produce similar effects to rough handling shock, except that they are highly repetitious. Successive cycles have a cumulative effect which can produce fatigue in packaging materials. Higher frequency vibrations tend to erode some of the protective materials. Each material is affected to a different degree by a specific stress situation.

The unit of pack is also a factor in determining the effects of vibrations. A single-unit inner package, singly packed, is affected less than multiple units of inner packages which are allowed to rub together. Palletized packages may be allowed to rub with little degradation. Depending on the weight of the package, the manner of stowage, and the force of the shock or vibration, stowed packages may be allowed to bounce or rise from the floor and move against walls or other restraint systems.

Large shipping containers are used with all modes of transportation; therefore, cargo being so moved must be packaged in anticipation of the shocks and vibrations of each mode. Because the container is rigidly fixed to the transport, there is no isolation of the shocks and vibrations. Minimizing the effects on cargo depends on the effectiveness of the restraint system.

While ammunition and explosives are sensitive to shock and vibration, the components are also very sensitive to high temperatures and humidity. These conditions are damaging to both mechanical and explosive components. Explosive components are extremely unstable at elevated temperature, and even more so with the addition of moisture. Corrosion of metal parts

because of high humidity can prevent operation and deter mechanical functionability of the fuze and even the complete round. Very high temperatures, over 160°F, can deteriorate the eutectic structure of certain alloys, and the reduced strength can affect ballistics and possibly user safety.

Results of studies of storage temperatures around the world are summarized in Appendix A.

The effects of unusual temperatures are more critical in the presence of moisture. Results of humidity studies are summarized in Appendix B.

Some evaluation of the degree of moisture protection provided by ammunition packaging was made using groups of 30 samples. Tests followed Aberdeen Proving Ground Material Test Procedure 4-2-820 with modifications to Table I and consisted of subjecting the samples to a 35° temperature cycle (70°F to 105°F) at 100% RH for 28 days. Prior to the test, samples were oven dried to remove moisture in the packing materials. A measured amount of desiccant used inside each package was weighed after the test to determine the amount of moisture allowed inside. Figure 14 is a graphical comparison of fiber containers for 105 mm howitzer ammunition loose and packed in wood boxes. These results show that elimination of the outer box should not allow the ammunition to be adversely affected by natural environments. Figure 15 is a comparison of mortar packaging with the wax-dipped overwrap and the same fiber containers without the wax. In this case the results are too close to make statistical inference, and additional tests are required with larger sample sizes.

Control of Environments

Before considering the degree of protection required, an analysis was made to ascertain whether controls could be used to lessen the severity of environmental effects.

Control of handling and transportation environments is difficult, if not impossible. During the life cycle of any ammunition item, it can be transported by any and all modes available, and handled by every method and type equipment.

Each transportation mode has peculiar characteristics which have varying effects on the cargo being moved. Truck transportation is characterized by relatively medium impact loads and low frequency medium

amplitude vibrations, rail by medium to high impact loads and low frequency medium amplitude vibrations, air by low impact loads and high frequency low amplitude vibrations, and sea by very low impact loads and low amplitude vibrations over a wide frequency range. Because the conditions, such as road surface, weather, equipment maintenance, etc., which vary those characteristics are so difficult to control, the induced environments are likewise difficult to control.

Like transportation, handling is difficult to control. Both require a great variety of equipment, from forklift trucks to overhead cranes, used under varying conditions. The greatest variable, and the one most difficult to control, is the operator of the equipment. For low density items, such as missile warheads, handling can be controlled to some degree by special equipment and detailed procedures. This method is not practical for most ammunition items being moved in support of combat operations because of quantity and time.

It is generally agreed that the most severe common handling is found at the user level where, because of the lack of equipment, each box or round of ammunition is handled manually, since each package is in a weight class where handling multiple packs is difficult, troops often find it expeditious to throw or roll the package. With the large number of troops involved in ammunition handling at that level, it is very difficult to control handling methods.

As an alternative to environmental control, the package can be designed to mitigate vibrations and to structurally resist or soften shocks. To make such packaging designs effective under the most severe conditions would be cost prohibitive; therefore, design criteria are set to maintain serviceability under most conditions and to insure safety under the most severe conditions. Packaging designs are tested by TECOM to the degree of protection required. The most severe TECOM test, repetitive seven-foot drops, is designed to simulate user handling which might include dropping from the turret of a tank or over the side of a truck and could occur several times before use.

Improvement at the user level is a matter of education and command emphasis. However, in combat, when maximum emphasis must be given to the mission and when personnel and equipment are critical commodities, troops will probably tend to revert to the faster, easier, more severe handling methods.

There are two methods of protecting the cargo from moisture in a closed container: controlling the humidity or increasing the packaging.

Effective dehumidification depends upon removal of moisture from packaging in the closed container. This may require 1/3 to 1/2 lb of desiccant per pound of packaging. A MILVAN loaded with mortar or artillery ammunition would contain at least 4000 pounds of packaging materials requiring about 2000 pounds of desiccant. Humidity control of air breathing of a MILVAN would require about 0.9 units of desiccant per cubic foot, or about 62 pounds.

Control of humidity in containers by use of desiccant can be accomplished by one of three systems.

The most effective method is the use of a dynamic system in which internal air flow is forced through the desiccant during a drying cycle. During a reactiviation cycle internal air flow is restricted and outside air is forced through the desiccant, and a heating element is used to dry the desiccant for reuse. This system requires less desiccant than the systems described below.

Least effective is the static system of placing desiccant inside a closed unvented container. All moisture remains inside the container. Since there is no air flow through the desiccant, only air in close proximity is dried and convection is the only means for air circulation. High temperatures cause moisture in the desiccant to be boiled out, returning to the air. For this system to work effectively, more desiccant is required to hold the moisture than for other systems.

Between these two systems lies the third, in which air breathing of the container is routed through a desiccated vent. As air flows through the desiccant, moisture is extracted during both inhale and exhale periods. For this system to be effective air must flow through the desiccant; therefore resistance to airflow must be less than at any leakage point. A breather of this type was installed in the controlled humidity (CH) CONEX container using a horizontal tube for desiccant (Fig 16). The horizontal tube loses effectiveness as transportation vibrations cause the desiccant to settle (Fig 17), allowing the airflow to pass over the desiccant. This can be corrected by positioning the desiccant container so that air must flow vertically and always pass through the desiccant (Figs 18 & 19).

There are several problems with both airflow systems. The dynamic system must have a power supply, without which it is less effective than the unvented static system. Both systems require space which must be in a relatively fixed location for all cargo loads. Both systems require modifications to the container for installation which may be difficult for leased containers.

There is another possibility for maintaining low relative humidity in the closed container. Experiments have been conducted using small-diameter tubing and capillary action to prevent moisture transmission. Ventilator units using many small tubes could be fabricated for large shipping containers. The total number of tubes would be established based on the amount of air change and air velocity. Like the systems previously described, container modifications would be required.

Concepts for Reduction of the Levels of Packaging/Packing

Several areas where reductions in packaging design might result in cost savings were explored to determine significance.

Change of Materials: There is a continuing search for packaging materials to provide the minimum required protection for minimal cost. Most materials or manufacturing techniques satisfy only part of the protection requirements, and some other material must be used to double-pack the item for complete protection. Modern materials which have the strength and impermeability properties sought in packaging materials are usually cost prohibitive. Another problem in the materials search is availability, both immediate and continued. Even wood and paper, so widely used in ammunition packaging, are sometimes in short supply. There are no obvious openings for direct materials change; however, exploitation of other concepts may permit greater flexibility of material applications.

De-unitization: Unitization is the consolidation of a group of individual packages together for handling with equipment. Because standard unit load dimensions do not take into account large freight container sizes and weight limits, container capacity is seldom fully used. Elimination of unitized loads would allow packaged ammunition to be placed in the container and stacked to the optimum height. This action would save about $7 per unit load or $4.5 million for 105 mm howitzer ammunition during mobilization. However, it would significantly increase load plant

and depot handling costs and manpower. Depots receive, store, and ship unitized ammunition for $24 per ton which would increase to about $60-70 per ton for nonunitized packages. These savings can not be realized unless ammunition remains in the large shipping container from the load plant to the user.

Elimination of Wood Boxes: Since containerization significantly reduces the rough handling experienced by ammunition in transit, that protection could be reduced to a level commensurate with the actual environment. The wood box outerpack serves two purposes, physical protection and consolidation for ease of handling. Elimination of the wood box would provide significant savings (Table 1). Since there would be periods with ammunition outside the large container and handling and storage requirements a part of the actual box cost savings would be offset by increased cost of the fiber containers. Significant savings as indicated could still be realized. Some items are so employed that elimination of boxes is not practical; however, 105 mm howitzer, mortar, and tank ammunition represent a major portion of ammunition used.

Elimination of Wax Wrap: During combat operations in Southeast Asia (SEA) an increased mortar malfunction rate was blamed on moisture penetration and the container was provided with additional protection in the form of a wax dip over a vapor barrier wrap. As tests (Fig 15) show the wax wrap provides little additional protection, its elimination would provide a sizeable savings (Table 1). Such a change would be welcome by many troops who must handle the wax in warm and hot climates. This action will require thorough testing in large shipping containers to assure adequate protection would still be provided.

Modular Packs: Recognizing that the high density of most ammunition items results in some empty space with containerization, another concept is practical. The use of modular pack sub-containers would spread that void space equally by dividing the total space available into a specified number of units.

Major advantages of this type of system are:

Unitization is provided by the sub-container.

The sub-container provides some protection, allowing further reduction in packaging.

Interlocking assemblies can be used to provide load restraint inside the container.

Sub-containers are reuseable.

The protection provided by the large container allows greater flexibility for sub-container materials.

TABLE 1

Estimated savings by reduced packaging

Change	Per Round	Annual During Mobilization
Eliminate 105 mm Wood Box	\$1.20	\$21.6 million
Eliminate 81 mm Wood Box	\$ .72	\$ 4.7 million
Eliminate 4.2 in. Wood Box	\$1.71	\$ 3.4 million
Eliminate 81 mm Wax Wrap	\$ .19	\$ 1.2 million
Eliminate 4.2 in. Wax Wrap	\$ .18	\$ .36 million

Note: Mobilization production quantities estimated based on previous usage quantities.

Impact on Production Operations

Present production facilities are generally designed for outloading rail cars, with some shipping by large trucks. Because of limited facilities and the added time needed to black and brace large shipping containers, direct shipment from the plant is sometimes difficult. Plant modernization plans include MILVAN/container compatibility, so the main problem remaining is the time and cost of load restraint. The real problems to LAP operations are temporary storage and limited space in the packout area.

Impact on Logistics Doctrines and Operations

Massive use of large containers would require many changes in CONUS and off-shore base storage and maintenance operations. Present depot facilities are configured for igloo or magazine storage, and those structures are not built to accept the large containers. Since temporary storage of containers would have to be outside the present storage structures, additional real estate would be required or storage capability reduced. All depots and storage facilities would require equipment for handling large containers. Maintenance procedures for ammunition stored in large containers would require the additional operation for removal from the container. However, reductions to packaging may reduce some maintenance operations.

Under present doctrine the main purpose of the depot system and off-shore bases is to provide initial responsive supplies to a theater of operations while production facilities are mobilized to full capacity, a period of six to nine months. When production becomes sufficient all ammunition would be supplied to the theater of operations by direct shipments. Ammunition for peacetime training requirements is often shipped from depot stocks to provide rotation.

costs

Unloading and storage in CONUS depots costs about $10 per ton. Loading and preparation for shipment, including blocking and bracing of rail cars, costs about $14 per ton. Since one rail car contains about three times as much as one container, about three times the blocking and bracing is required for containers, and this cost is increased by $2 to $4 per ton.

In the communications zone (COMMZ), containerization presents new problems and advantages. Current doctrine calls for the bulk of theater supplies to be stored at rear depots in the COMMZ and shipped direct to the forward part of the combat zone. Containerization can be put to great use in implementing that policy, although TO&E organizations operating water terminals and storage facilities must be equipped to handle large containers. Temporary storage in large containers will require more hardstand area, more stringently constructed, than the same ammunition stored under present methods. Based on the effectiveness of throughput, stockage levels in the theater may be lowered. This would allow the possibility of theater stockage without greatly increasing real estate requirements. Other important considerations are management of records and control of containers. Because the containers have no document holders, allowance must be made for combat losses of containers, and for administrative losses due to records errors.

As the loaded containers are moved forward, security becomes a more important consideration. The container provides a degree of physical security by obscuring the contents and delaying access by saboteurs. In areas not protected from enemy observation, the size and shape of the large containers and groupings make effective camouflage difficult. In more forward areas, preparation of storage facilites is less adequate and often containers must be left on carriages during storage. This results in a high degree of mobility for ammunition stocks but it requires more carriages in the theater. Accurate control of containers is more important in the combat zone than in the COMMZ for insuring the proper stockage levels.

One significant advantage of temporary storage in large containers is the reduction of fire hazards. While testing to date indicates that the container will not deter explosive propagation sufficiently to allow reduction of quantity-distance factors, the container will prevent firebrand type burning debris from reaching the ammunition. Depending on the construction of the container, fragments may be stopped or slowed enough to prevent initiation of new fires.

Impact on User Operations

Containerization with policies strictly adhering to the scope of this study would have little effect on the using organization, because the user's first contact with the ammunition supply system is at the forward ASP, where ammunition would be removed from the container for issue. However, a mid-intensity combat situation normally emphasizes mission performance, often sacrificing established book doctrines, and large containers may be shipped forward of the forward ASP. This condition would occur most when the user requirement were for at least a container quantity or very near it, and the ASP commander easily realized his manpower savings by eliminating the unload-load operations through a few minutes of transportation coordination. The user, having no facilities or ramps for unloading, would then have to improvise.

Proposed and implemented reductions of organizational vehicles, recommended by the DA Wheels Study Group - REVA, greatly reduce the organization's ability to pick up supplies. The likelihood of combat service support items being delivered to the Division Support Command (DISCOM) areas by theater Army Support Command (TASCOM) transportation assets is increased. That delivery is accomplished efficiently by dropping loaded trainers or containers and back-hauling the empties.

For high usage ammunition items, that delivery might go directly to an artillery firing battery gun site or to an infantry battalion combat trains area. An Infantry School concept visualizes container delivery well forward in the combat zone to brigade or battalion trains areas.

Large containers in the organizational area pose two problems, maneuver and camouflage. The maneuver problem can be partially solved by providing the organization with semitrailer fifth-wheel dollies to adapt the container chassis for towing with standard cargo trucks. The solution is adequate only when terrain permits maneuver of semitrailer vehicles. The using unit can sometimes establish a trailer drop point nearby and use organizational vehicles to shuttle the ammunition. Maneuver problems may be decreased by development of the heavy lift helicopter, and will depend on its availability in forward areas of the combat zone. A problem is posed to camouflage by the size and rigid shape of the container, though this may be solved by careful application of camouflage principles. Partially offsetting the camouflage disadvantage is the reduction of traffic flow into and out of the area by about one-third.

One problem to the user with present shipping methods is sometimes the disposal of packaging materials and unused propellant increments. The problem is mainly one of observation security because large piles of packing materials disclose position location as does disposal by burning. Large empty containers in the organizational area can be used to retrograde these items for disposal in a rear area.

Concepts of package reduction are of concern to the user. The important consideration for the user is that the package must be simple and be easy to open so as to not slow the rate of fire. The package should also be free of excess tare weight. Changes to ammunition packaging brought about by complete containerization may be beneficial to the user, but it is important that the level of protection provided when ammunition is delivered to the user be at least equal to that of the present package.

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APPENDIX A

TYPICAL STORAGE CONDITIONS

Studies have been made to determine storage conditions for various areas of the world. Typical temperatures and extremes are shown in Table A1 through A3. The results presented give an indication of temperatures to be expected inside explosive hazard magazines; however, the apparent differences in temperatures between locations may be, to some extent, due to the construction of the individual magazines. Figure 7 through 10 show typical daily temperature and humidity variations. Airflow is a primary factor in keeping warehouse or above-ground magazine temperatures low relative to outside air. For storage in closed, sealed container such as CONEX's, van-type trucks, or railroad boxcars, temperatures are high. Due to the lack of air circulation, these inside temperatures may at times even exceed those of the outside air. Temperatures in the holds of cargo ships remain very constant with about $20^{o}F$ between high and low temperatures and high temperatures seldom exceding $90^{o}F$.

TABLE A1

Temperature summary by station and magazine type for storage in CONUS

Storage locations	Magazine type	Months[a]	N[b]	Number of maximum temp, equal to or greater than			Recorded temp, °F	
				90°F	100°F	110°F	Max	Min
NAD, Portsmouth, Va	Earth	156	9,562	388	9	0	107	23
	Non-earth	157	38,564	5368	551	31	115	11
NWD, Charleston, SC	Earth	47	18,550	5	0	0	91	28
NAD, Crane, Ind	Earth	37	4,507	0	0	0	86	20
NAD, McAlester, Okla	Earth	114	5,231	57	0	0	99	18
NAS, Dallas, Tex	Non-earth	46	11,180	2146	220	0	106	11
NAS, Corpus Christi, Tex	Earth	24	3,838	397	0	0	99	40
	Non-earth	24	1,877	246	0	0	95	27
NWS, Concord, Calif	Earth	139	15,271	31	0	0	97	32
MCAS, El Toro, Calif	Earth	69	3,967	22	4	2	112	32
	Non-earth	58	894	162	9	0	106	32
NWS, Seal Beach, Calif	Earth	60	17,403	0	0	0	88	42
	Non-earth	50	200	2	0	0	92	40
NOS, Indian Head, Md	Earth	36	20,219	177	6	0	104	18
	Non-earth	39	5,972	348	6	0	107	10

[a]Length of time in months.

[b]Number of data points represented in the sample.

TABLE A2

Temperature summary by station and magazine type for storage in the Pacific

Storage Locations	Magazine type	Years[a]	N[b]	Number of maximum temp, equal to or greater than 90°F	Number of maximum temp, equal to or greater than 100°F	Maximum recorded temp
Naval Air Facility Naha, Okinawa	Earth-covered	3	503	45	1	107
	Non-earth-covered	3	566	181	6	105
Naval Ordnance Facility Sasebo, Japan	Earth-covered	4	296	0	0	84
	Non-earth-covered	1	352	18	2	100
Marine Corps Air Station Iwakuni, Japan	Earth-covered	3	2,680	133	33	114
	Non-earth-covered	3	929	157	20	117
Naval Air Station Atsugi, Japan	Earth-covered	1	907	6	1	100
	Non-earth-covered	4	1,961	183	0	99
Naval Ordnance Facility Yokosuka, Japan	Earth-covered	1	1,879	3	0	90
	Non-earth-covered	1	825	32	0	96
Naval Ammunition Depot, Oahu, Hawaii	Earth-covered	6	39,155	128	0	98
	Non-earth-covered	6	7,165	2,203	0	99
Naval Air Station Barbers Point, Oahu, Hawaii	Earth-covered	2	2,146	95	3	101
	Non-earth-covered	2	2,837	141	1	100
Naval Magazines, Guam	Earth-covered	3	6,739	35	0	98
	Non-earth-covered	3	679	471	79	104
Naval Air Station Agana, Guam	Earth-covered	3	6,518	416	8	108
	Non-earth-covered	2	2,421	311	1	105
Naval Magazines, Republic of the Philippines	Earth-covered	5	9,100	661	1	100
	Non-earth-covered	2	140	69	56	110
Naval Station Sangley Point, Republic of the Philippines	Earth-covered	1	3,479	476	1	101
	Non-earth-covered	1	383	8	0	98

[a]Length of time in complete calendar years.

[b]Number of data points represented in the sample.

TABLE A3

Temperature summary by station and magazine type for storage in the Caribbean and Mid-Atlantic

Storage locations	Magazine type	Months[a]	N[b]	Number of maximum temp, equal to or greater than			Recorded temp, ^{o}F	
				$90^{o}F$	$100^{o}F$	$110^{o}F$	Max	Min
Naval Air Station Guantanamo Bay, Cuba	Earth covered	39	8,861	1,043	1	0	100	60
	Non-earth Covered	21	2,537	222	0	0	98	55
Naval Station Roosevelt Roads, Puerto Rico	Earth covered	38	98,515	15,929	27	1	110	52
	Non-earth covered	30	5,473	1,359	3	0	102	55
Naval Station Bermuda	Earth covered	31	15,177	599	0	0	98	47
	Non-earth covered	33	2,741	202	0	0	98	40
Naval Air Facility Azores	Earth covered	37	7,616	0	0	0	86	35

[a]Length of time in months.

[b]Number of data points represented in one sample.

APPENDIX B

Temperature and humidity variations in closed containers

To study various humidity environments requires a simple knowledge of humidity-moisture-temperature relationships. There are two methods of measuring humidity depicted in overly simplified form by Figure 11. The most common is relative humidity, which is the percentage of saturation of the air at a given temperature. Absolute humidity is the actual moisture content of the air, usually expressed in grains per cubic foot. Air with one hundred percent relative humidity at $70^{\circ}F$ has eight grains per cu ft, which would be only forty percent if that air were heated to $100^{\circ}F$. If that same air were cooled to $40^{\circ}F$, five grains of moisture would be condensed out of the air.

The humidity level in well ventilated storage facilities and vehicles stays very near that of the outside air. When ventilation is restricted, humidity of the inside air will slowly rise to equal that of the outside air; but when the outside humidity goes down, the humidity inside does not unless the container remains in a very dry outside environment for an extended period of time. If the container is completely sealed, changes in the outside air have no effect on the absolute humidity. Figure 12 is a typical "Lag Loop" or graphical plot of the continuous variation of relative humidity and temperatures in a closed, sealed, empty container. As the moisture content remains constant, the loop is closed and flat; and relative humidity varies with temperature. The loop in Figure 13 represents the conditions inside a closed container with packaged cargo inside. The moisture in the packing materials is boiled out as the temperature rises, causing an increase in the absolute humidity of the air. If the container leaks, as do most shipping containers, the resulting rise in humidity causes the packaging materials to become saturated.

Several studies of humidity accumulation in shipping containers have been made by various organizations. Results of one such study are shown in Table B1 for one area in the study. The same principles can be applied to MILVAN and large commercial containers having semi-restrictive free breathing characteristics. When new, the container will withstand the air pressures resulting from temperature differences where the inside temperature is $6^{\circ}F$ higher to $10^{\circ}F$ lower than the outside air. This resistance is decreased as the container is used and transported, but still retains enough to allow moisture accumulation. Assuming the air space is 1095 cubic feet and the van is closed at $70^{\circ}F$ with a day/night temperature

difference of thirty degrees and the outside relative humidity remains at 100%, calculations show that moisture would begin to condense about the tenth day. After a month the accumulation would be about one and one-half pints, and each succeeding month would add about two pints. Table B2 illustrates how the principle works. Ammunition cargo would fill about half of the air space, reducing the airflow factor, which is inversely proportional to the amount of cargo contained. Since the outside conditions will not be as severe as described above over a long period of time, even less moisture would be condensed. Over a period of six months about four pints could accumulate.

Tests being conducted at Savannah Army Depot and other locations by the AMC Ammunition Center are inconclusive. Containers have to be opened periodically for change of record paper and rewinding timers, and resulting data is affected by that opening and exposure such that it represents a series of short-term tests.

Commercial shippers of containerized cargo have experienced some moisture damage. Insurance statistics do not include such data as the length of time cargo was in the container, outside weather conditions or container damage. A lack of details precludes the use of damage reports as conclusive evidence of moisture accumulation.

TABLE B1

Average water gain per cubic foot at Oklahoma City

Property	May	June	July	Aug	Sep	Oct
Average ambient high, ^{o}F	78	87	92	92	85	73
Average ambient low, ^{o}F	58	67	71	70	63	52
Average internal high, ^{o}F	95	102	107	107	98	83
High relative humidity %	82	82	80	80	82	79
Low relative humidity %	57	55	48	48	51	55
Average relative humidity %	70	69	64	64	67	67
Weight of inhaled water, grams/ cu ft	.76	.89	1.01	1.01	.79	.51
Cumulative sum grams/cu ft	.76	1.65	2.66	3.67	4.46	4.97

TABLE B2

Calculated water accumulation in empty MILVAN = 1095 cf

Day	Exhale 62 cf (grains)	Inhale 62 cf (grains)	Total Moisture (grains)	Condensed Moisture (grains)	RH @ 70^{o}
0			3285		40
1	186	930	4027		45
2	228	930	4731		52
3	268	930	5393		60
4	305	930	6018		68
5	341	930	6607		75
6	374	930	7163		81
7	406	930	7687		87
8	435	930	8182		92
9	463	930	8649		99
10	490	930	8760	329	100
11	496	930	8760	434	100
12	496	930	8760	434	100

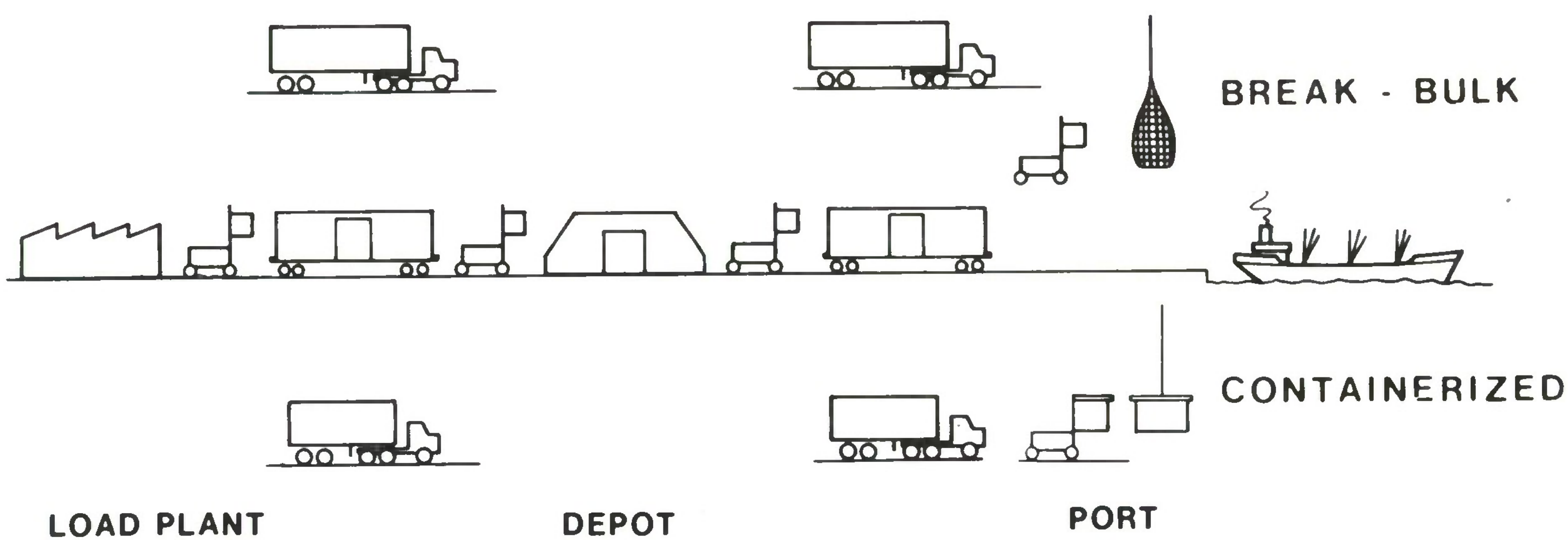

Fig 1 Transportation and handling in CONUS

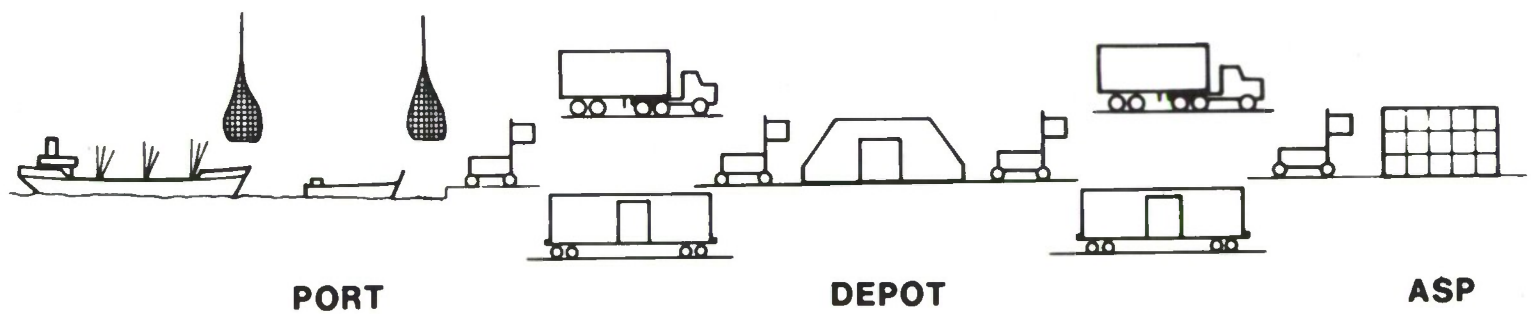

Fig 2 Transportation and handling of break-bulk ammunition overseas (COMMZ)

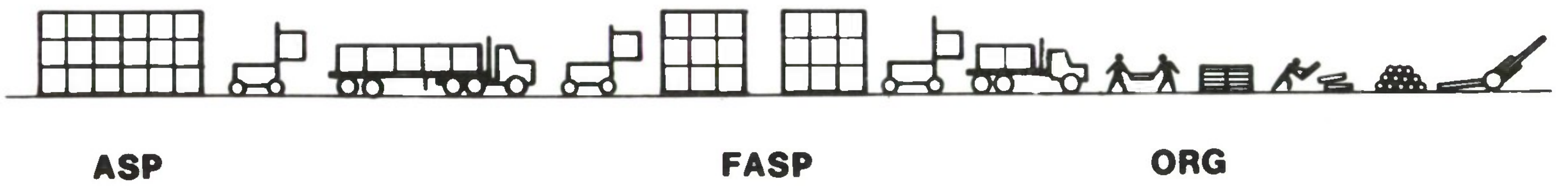

Fig 3 Transportation and handling of break-bulk ammunition in overseas forward areas

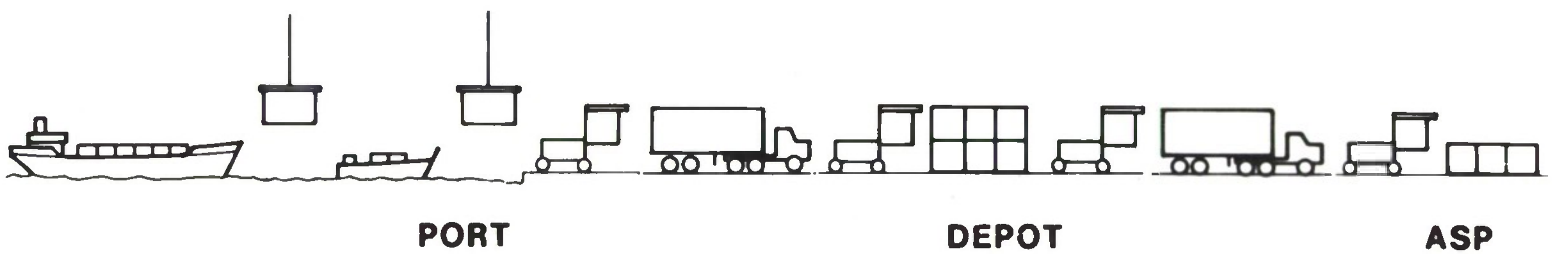

Fig 4 Transportation and handling of containerized ammunition overseas (COMMZ)

Fig 5 Transportation and handling of containerized ammunition in overseas forward areas

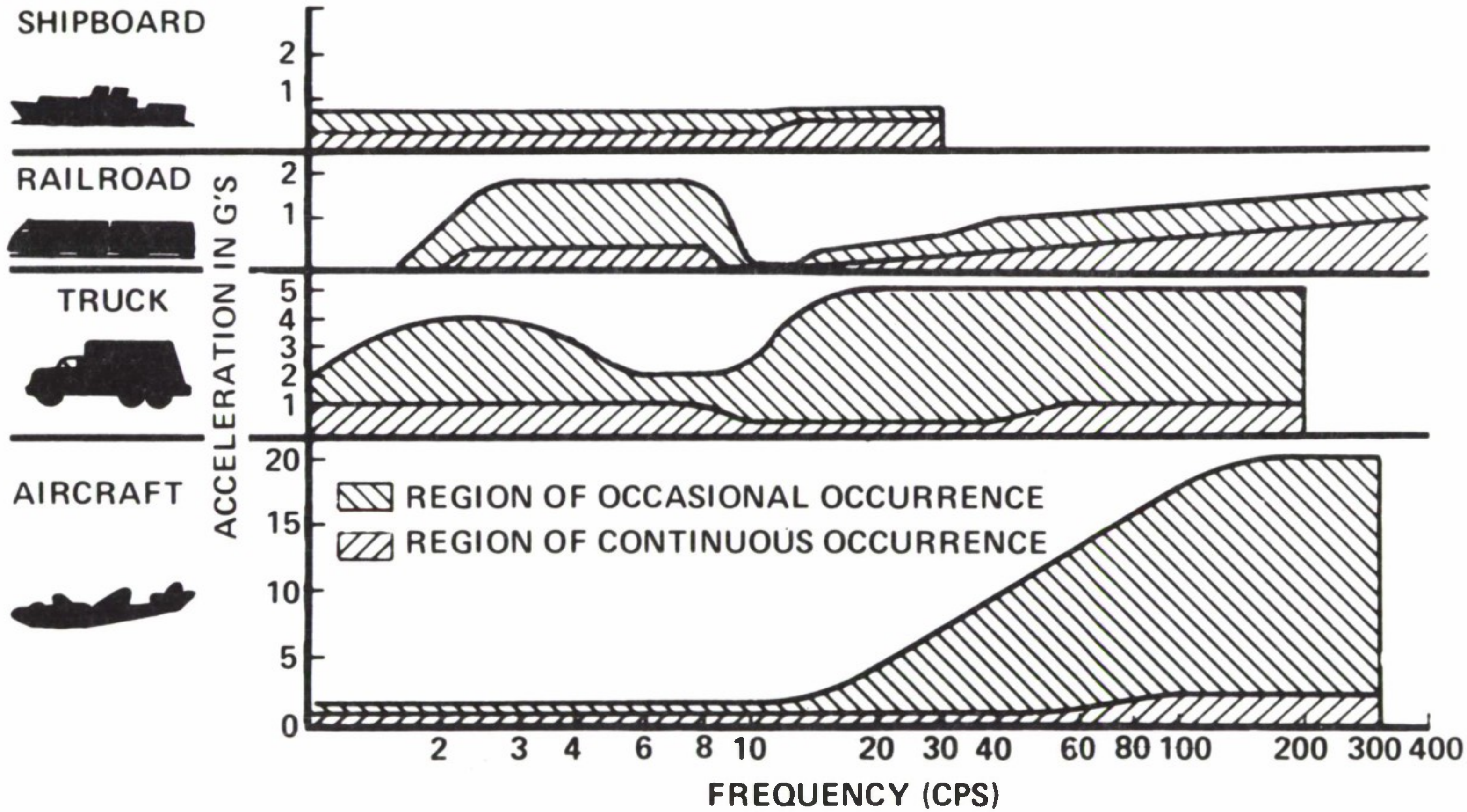

Fig 6 Transportation vibration spectra

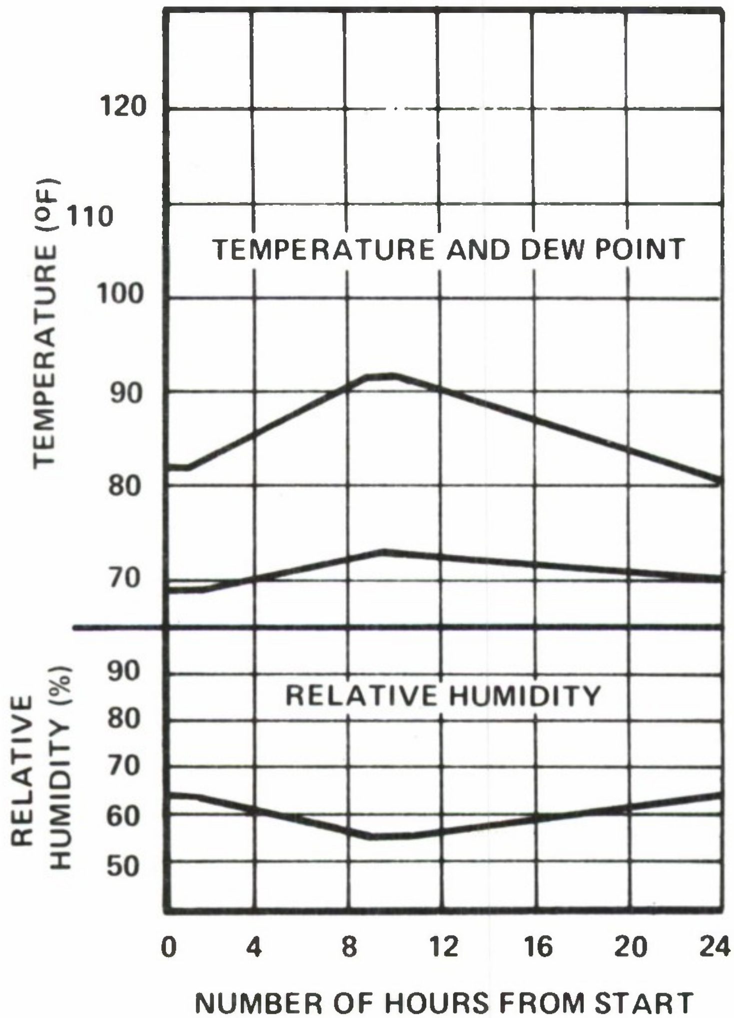

Fig 7 Daily temperature and humidity cycle for storage in temperate summer warehouses

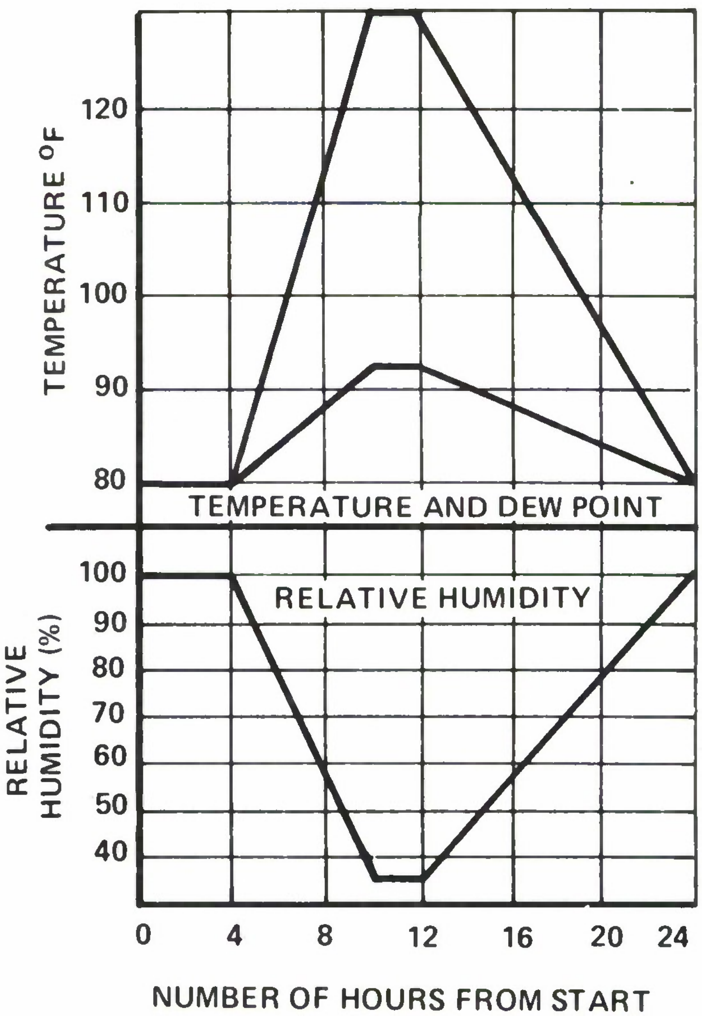

Fig 8 Daily temperature and humidity cycle for storage in extreme desert climatic (unventilated shelter)

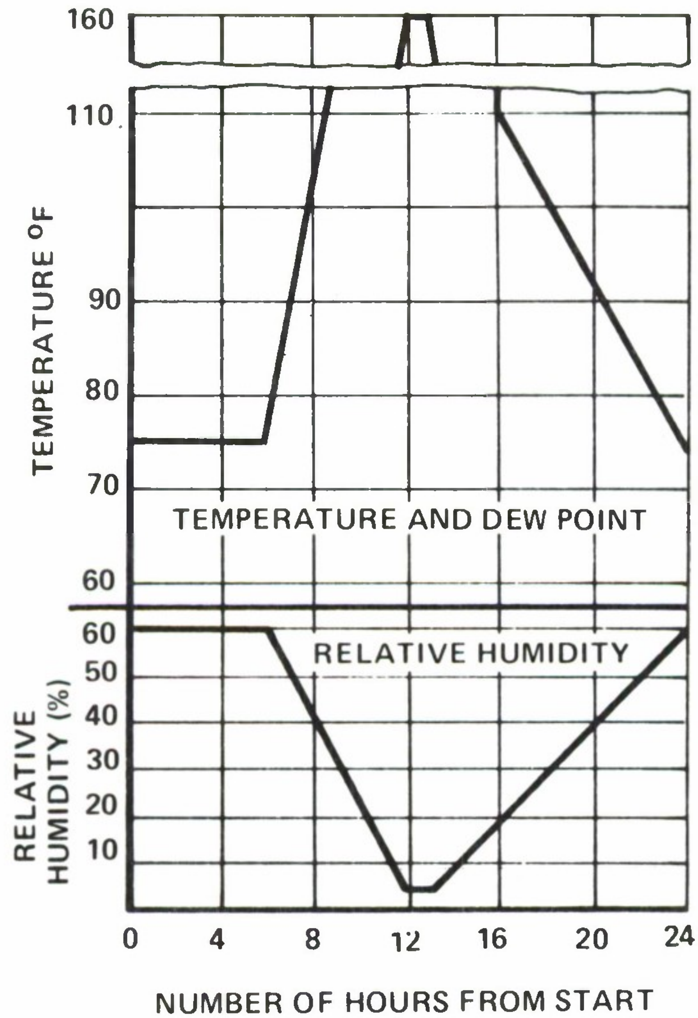

Fig 9 Daily temperature and humidity cycle for storage in moist tropical beachhead (outdoors)

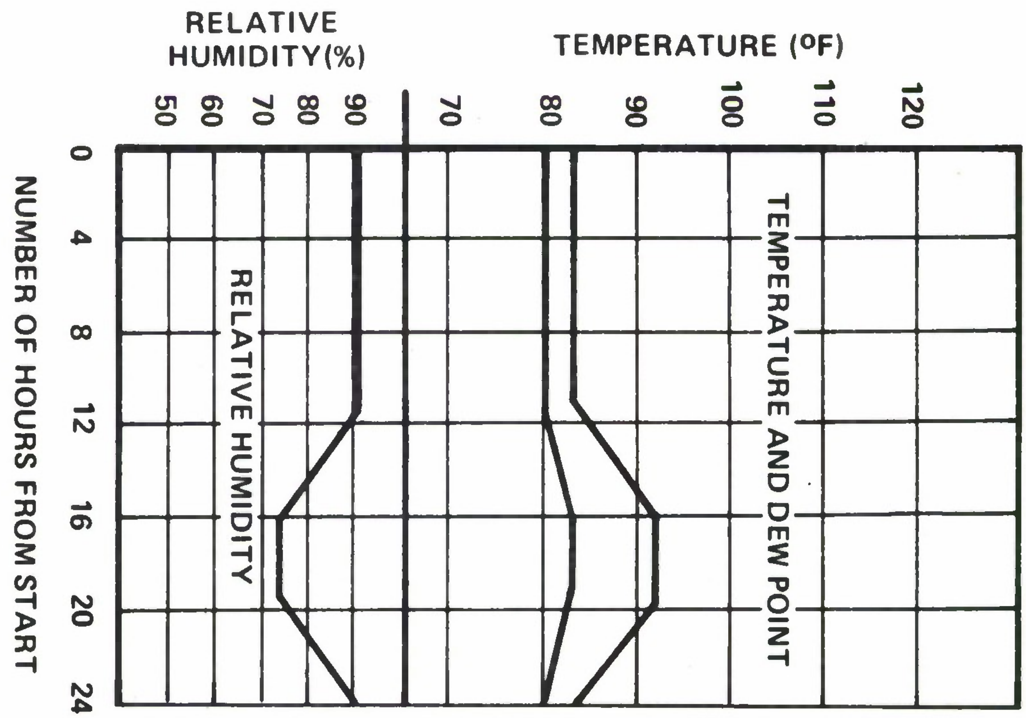

Fig 10 Daily temperature and humidity cycle for storage in moist tropical warehouses

AIR TEMPERATURE	RELATIVE HUMIDITY PERCENT	MOISTURE GRS CU FT
100° F	100 40 20	20 8 4
70° F	100 40 20	8 3 1.5
40° F	100 40	3 1

Fig 11 Temperature-humidity-moisture relationships

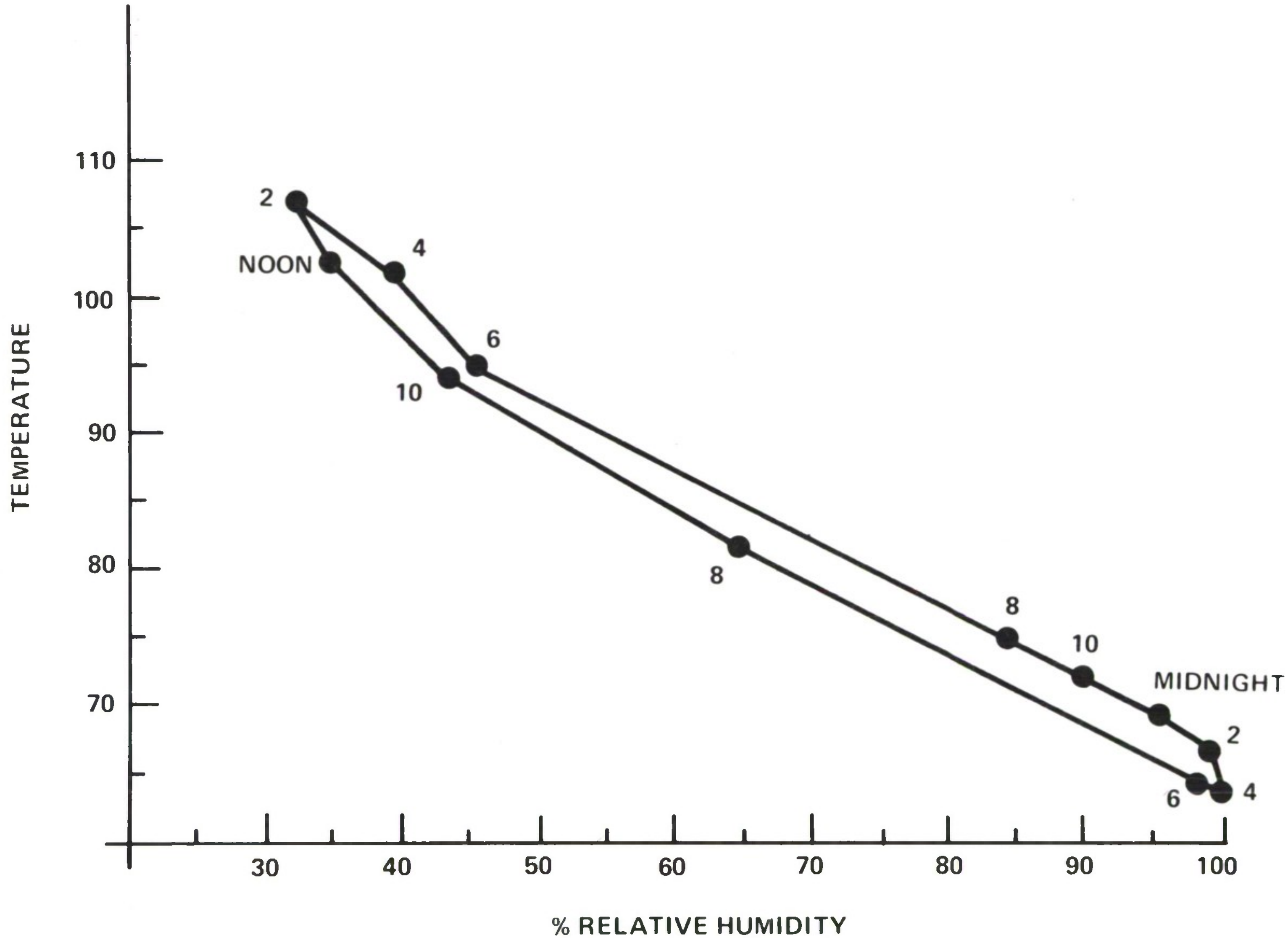

Fig 12 Temperature-humidity cycle in closed, sealed empty containers

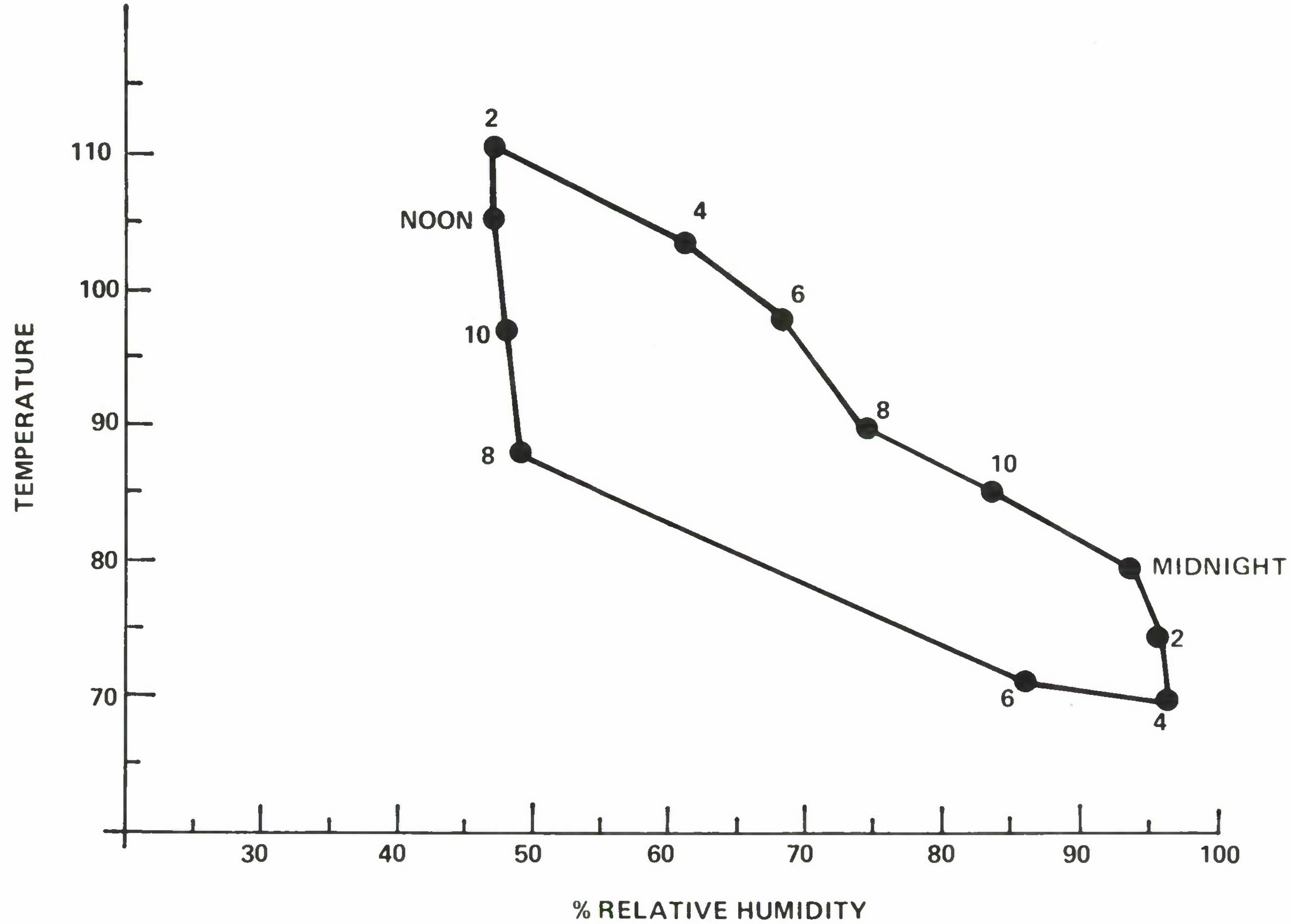

Fig 13 Temperature-humidity cycle in closed, sealed containers with packaged cargo

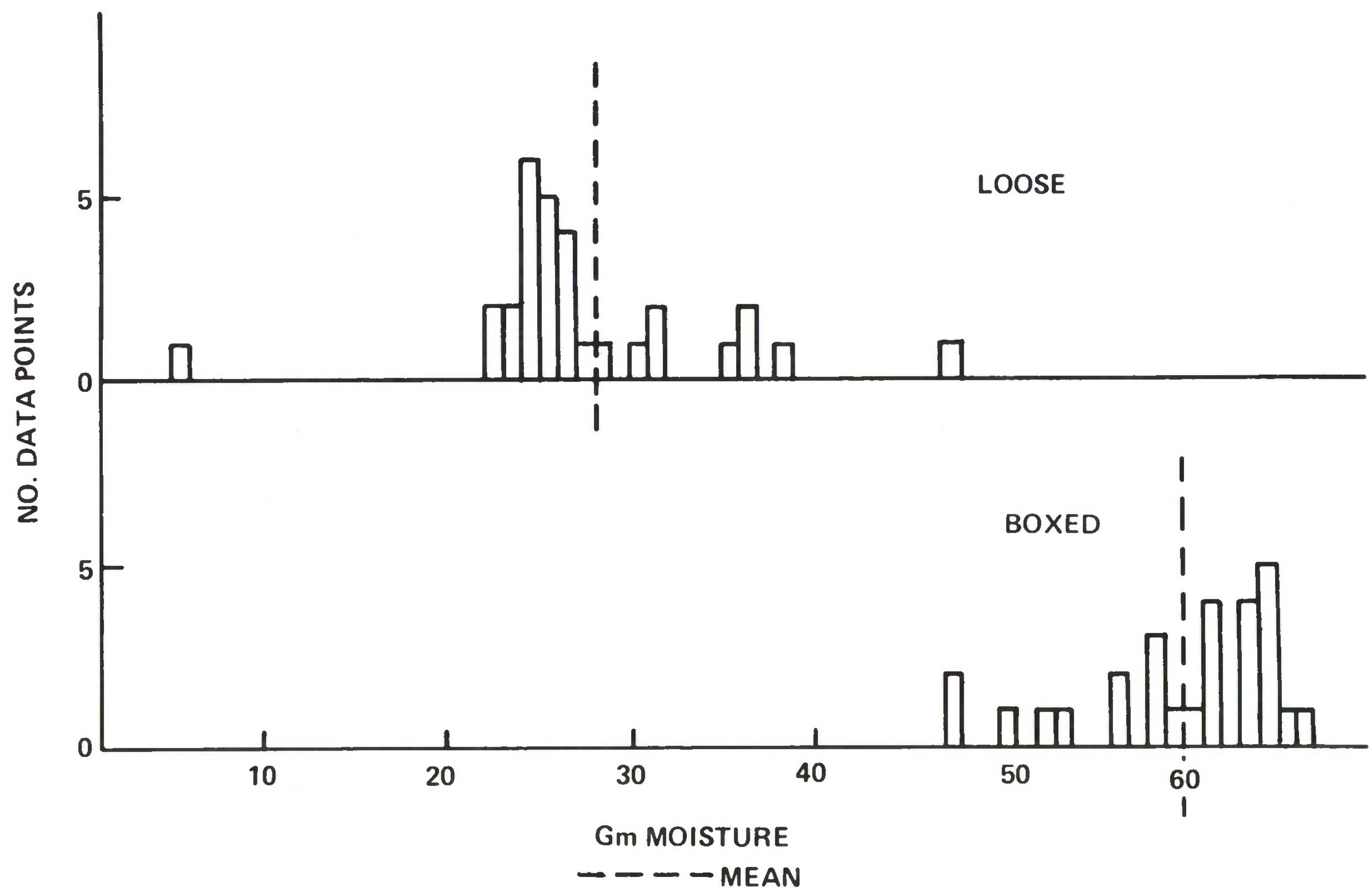

Fig 14 Water gain in PA55 fiber tube ammunition containers boxed and unboxed

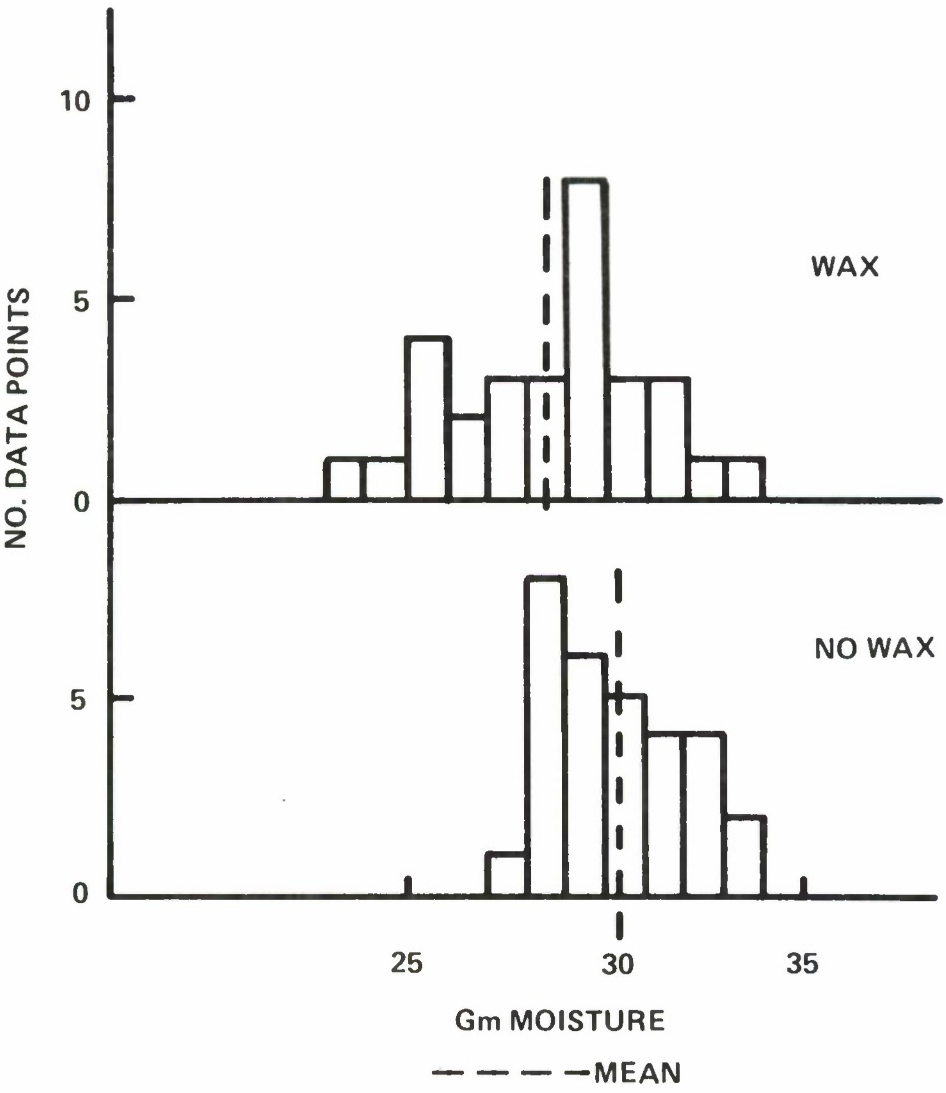

Fig 15 Water gain in M242 fiber tube ammunition containers with and without waxed vapor barrier

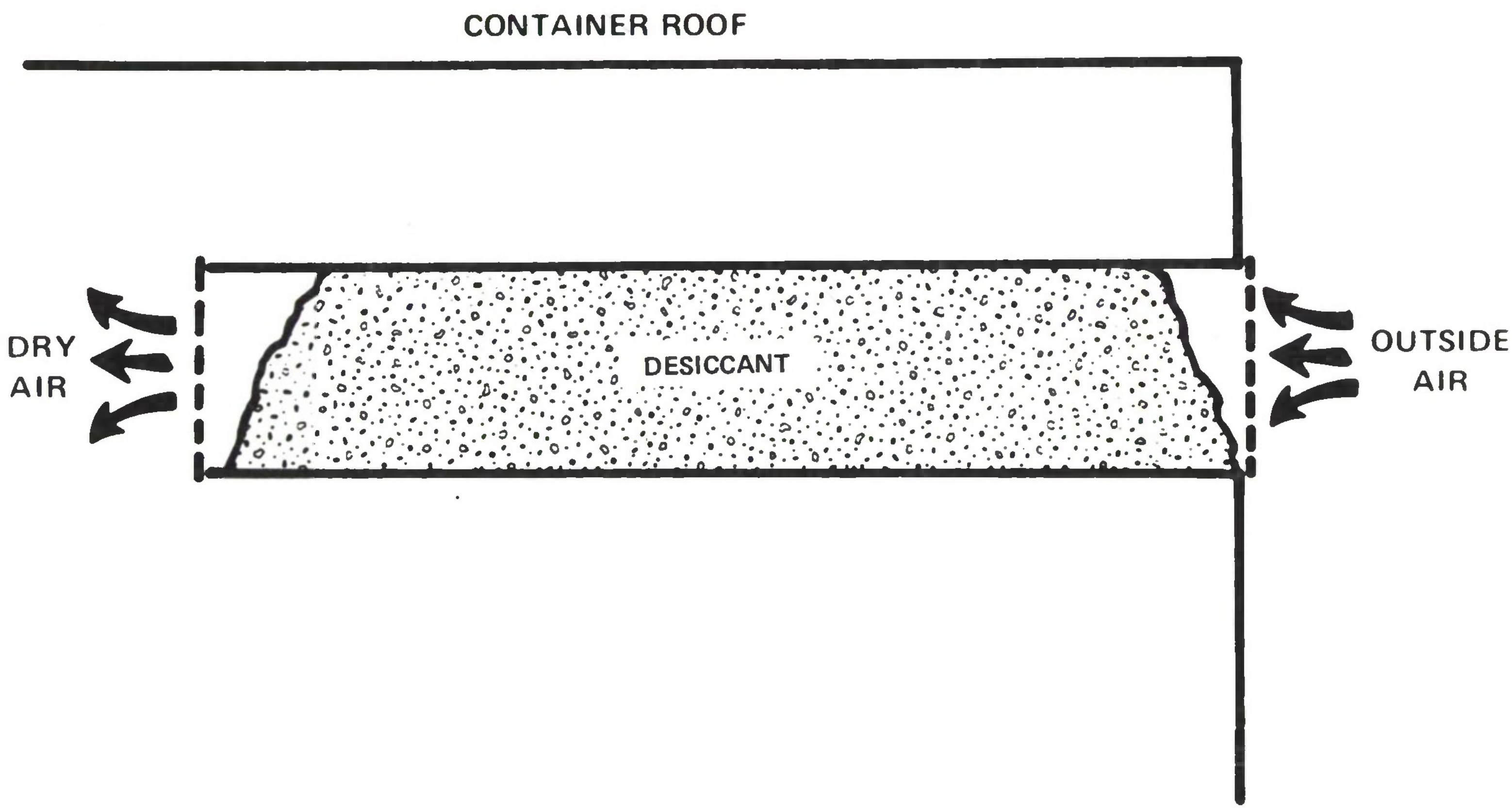

Fig 16 Horizontal desiccant breather operation in storage

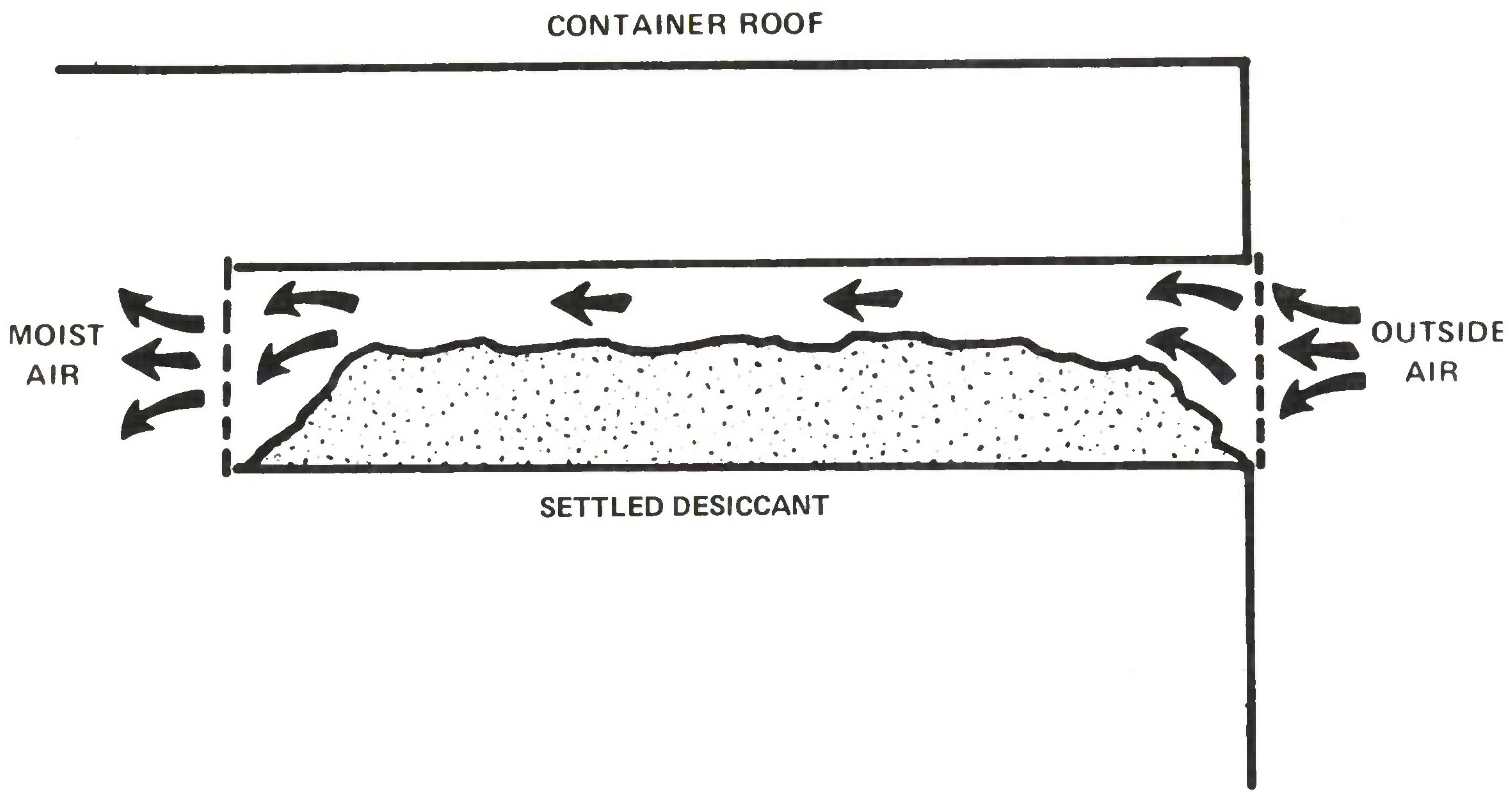

Fig 17 Horizontal desiccant breather operation after handling and transportation

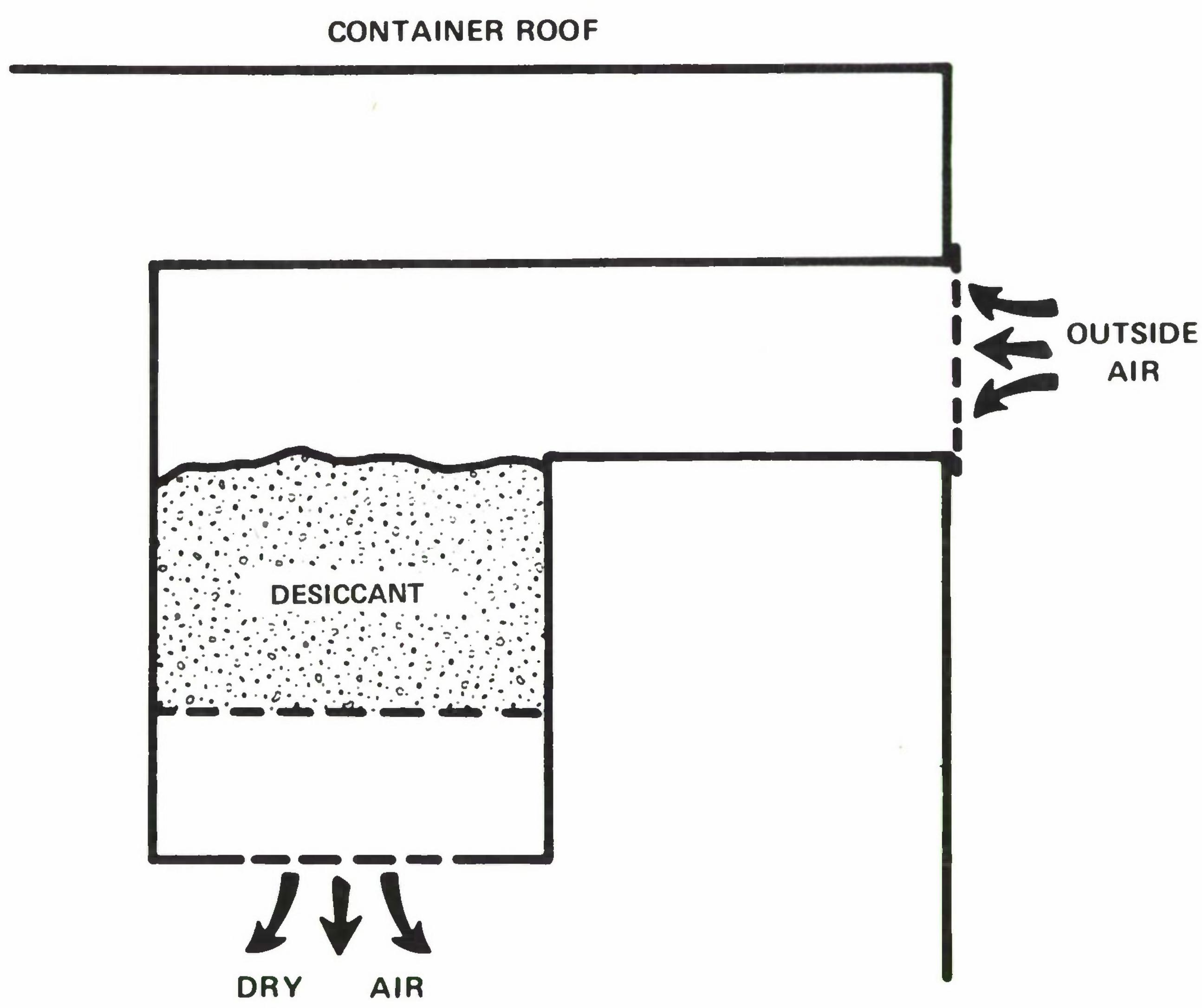

Fig 18 Vertical desiccant breather operation in storage

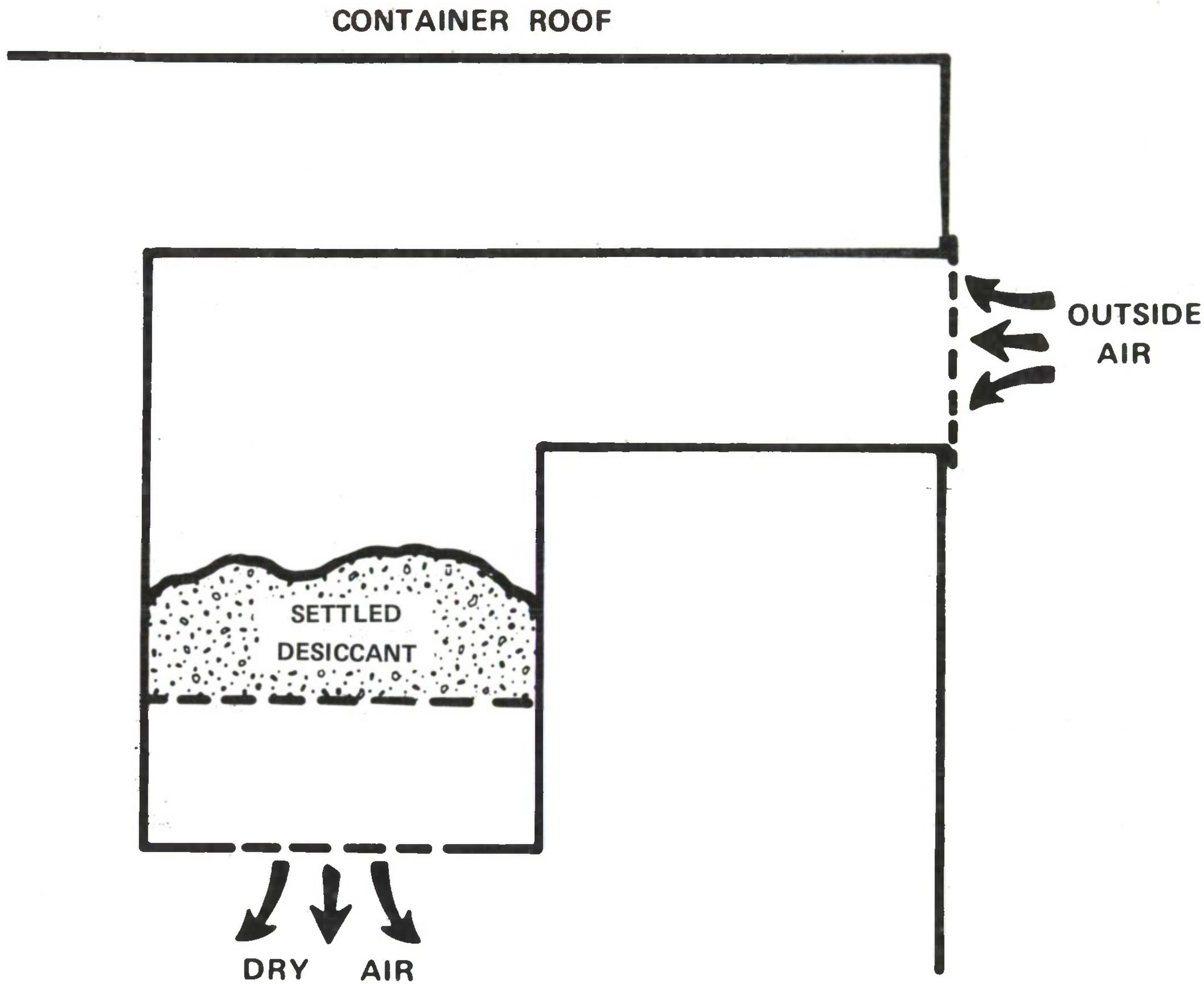

Fig 19 Vertical desiccant breather operation after handling and transportation

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